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SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX. CONSTRUCTION COST TRENDS MUNICIPAL WASTE TREATMENT WORKS

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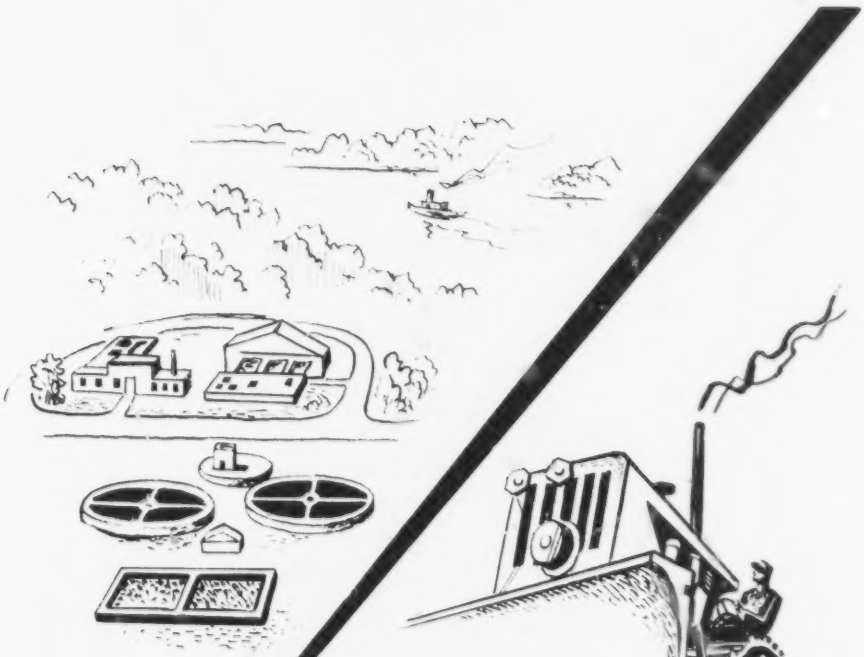

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37

SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX

Construction Cost Trends
Municipal Waste Treatment Works

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
Washington, D.C. 20201

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FOREWORD

Construction costs have risen steadily since the mid-1930's. The rate of increase varies between the different construction elements such as labor, materials and equipment, and between the different types of construction.

Contract award data have proven useful for evaluating progress in waste treatment works construction and in estimating future construction requirements. During a period of rising costs, however, such data need to be adjusted to a standard base to assure comparability. This can be done through use of an appropriate construction cost index. Unfortunately, existing construction cost indexes were designed for types of construction other than waste treatment works or are too general in nature for this purpose.

After a preliminary investigation of earlier work, the design of a construction cost index for municipal waste treatment plants was undertaken nearly 2 years ago by the Construction Grants Branch, Division of Water Supply and Pollution Control. Personnel of the Construction Statistics Division, Bureau of the Census, and of the Department of Civil Engineering, Northwestern University, were very helpful in the initial stages of this work. The treatment plant construction cost index, now complete, is presented in this report. A companion cost index for sewer construction is currently under development.

This work was produced by Prof. Raymond M. Jones of Howard University under the supervision of Mr. Peter P. Rowan, Chief, Evaluation Section, Construction Grants Branch, Division of Water Supply and Pollution Control, Public Health Service. Engineering consultation was provided by Mr. Paul D. Haney, Black & Veatch, Consulting Engineers, Kansas City, Mo., and computer programing by Mr. William H. Mills, Jr., of the Basic Data Branch, Division of Water Supply and Pollution Control, Public Health Service.

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INTRODUCTION

Grants-in-aid for municipal waste treatment works construction authorized under the Federal Water Pollution Control Act in 1956, have been accompanied by a steady increase in the dollar volume of construction contracts awarded for these facilities. An accurate assessment of the increased construction activity and estimate of future construction needs require a thorough understanding of the changing purchasing power of the local and Federal funds invested in waste treatment works construction. One approach was to consider cost indexes already available. An examination of existing construction cost indexes, however, disclosed no apparent applicability to waste treatment works construction and it became evident that indexes designed specifically for sewage treatment plants and sewers were needed. Subsequently a sewage treatment plant construction cost index was developed and is the subject of this report, the latter portion of which discusses the several cost indexes examined.

A price or cost index number is the ratio of the sum of the prices or costs of a product or service in a given period divided by the sum of the prices or costs for similar products or services for a base period (*1*). A price index differs from a cost index in that a price index is influenced by the prices of factors, whereas a cost index is influenced by prices and quantities of factors entering the "standard product" at two different periods. More specifically, a

$$\text{Construction Price Index} = \frac{P_{1_a}+P_{2_a}+P_{3_a}+\cdots P_{n_a}}{P_{1_b}+P_{2_b}+P_{3_b}+\cdots P_{n_b}}\times 100 = \frac{\sum P_a}{\sum P_b}\times 100 \qquad (1)$$

where

P_1, P_2, $P_3 + \cdots P_n$ are prices of the factors making up a "standard product" of construction, "a" is any given construction period, and "b" is the base period of construction; and a

$$\text{Construction Cost Index} = \frac{P_{1_a}Q_{1_a}+P_{2_a}Q_{2_a}+P_{3_a}Q_{3_a}+\cdots P_{n_a}Q_{n_a}}{P_{1_b}Q_{1_b}+P_{2_b}Q_{2_b}+P_{3_b}Q_{3_b}+\cdots P_{n_b}Q_{n_b}}\times 100 = \frac{\sum P_aQ_a}{\sum P_bQ_b}\times 100 \qquad (2)$$

where

$P_1, P_2, P_3 + \cdots P_n$, and "a" and "b" are the same as in equation (1) and Q_1, Q_2, $Q_3 + \cdots Q_n$ are the quantities of the factors making up a "standard product" of construction.

The "standard product" of construction in this development is a sewage treatment plant of fixed design and specifications, combined in proper proportion to represent the series evaluated. The factors entering are: skilled and common labor, construction materials, process equipment, construction equipment, and overhead and profit.

A cost index may either be a "floating base" type or a "fixed base" type (*2*). The "floating base" refers to a quantity variable; i.e., the quantity (Q) factors may vary from period to period with the price (P) factors either increasing or decreasing due to internal or external causes. The "fixed base" index has constant quantity factors; i.e., there is no change in the quantity (Q) factors from period to period and consequently the cost may vary due to external causes only. Indexes of each base type are common.

This report deals with the development of a fixed base, weighted, cost index, which is believed to be a substantially accurate indication of the purchasing power of funds invested in sewage treatment plant construction. There is no better means of measuring the relative purchasing power of money than is offered by a comparison of the changing prices of the commodities with which an industry deals in the units on which business transactions are based.

BACKGROUND

In its broad and generic meaning, an index number is an average of relatives or variations. If the variations measured are those of commodity prices, an index of prices is obtained; index numbers of wages, interest rates, profits, production, and a large number of other measurable phenomena also have been computed. Each of the applications of index numbers may be subject to peculiarities of its own; and, in every case, the average is drawn for the specific purpose for which it can appropriately be used.

Index numbers were first used to measure the rise or fall of prices, i.e., the inverse movement of the general exchange value of money; and the term itself was coined in this connection. In 1838 Porter used the term "index prices," and in 1869 the *London Economist* (*2*) called the sum of the relatives of 22 prices, which it compiled, the "total index number." The term "index number" quickly came into common usage to denote the prices of individual commodities averaged at each period, their total sum, or an average of them—this last meaning being the most popular.

A price index number, whether it relates to all prices, or merely to those of a single commodity group, is a series of averages for price distribution at successive dates. As such, it measures only the change in the general tendency of the distribution. It fails to reveal the changes in their internal structure and conceals changes which may reflect on the reliability of the index number as a representative value. Only within the last several decades has attention been centered on these aspects of changing prices. Previously, the complex variations in the internal price structure, which are of vast economic significance, were apt to be regarded merely as troublesome obstacles to the calculation of reliable averages.

History reveals that price indexes fail to reflect the changes in internal structure, such as technological advances, progressive improvements in business organizations, and changes in the prices of the various elements of production, all of which may result in increasing output being accompanied by decreasing money costs.

Economically, "cost" means the surrender or destruction of value, or the performance of some irksome activity as a means of production of commodities or the acquisition of income. The classical school gives three rival explanations of cost: namely, (1) psychological or pain costs, (2) labor costs, and (3) money costs, or, expenses of production (*3*). Construction cost encompasses all these philosophies and includes materials, machines, men, and money. More specifically, construction cost is equal to the sum of the cost of:

(1) Materials =concrete, lumber, iron, steel, etc., used in construction;
(2) Machines =process equipment and contractor's equipment used in construction;
(3) Men =skilled and common (heavy construction) labor employed during construction; and
(4) Money =overhead charged and profit earned during construction.

or,

$$\text{Construction cost} = M_1 + M_2 + M_3 + M_4 \qquad (3)$$

NEED FOR INDEX

A review of the several general-purpose construction cost indexes, such as those of the American Appraisal Co., Associated General Contractors, E. H. Boeckh & Associates, Marshall & Stevens, and *Engineering News-Record* (ENR), disclosed no adequate basis for assuming that any of these accurately measure the changing cost of waste treatment plant construction due to weight and/or price bias. From a practical standpoint, though, an index such as the ENR Construction

Cost Index (*4*) possesses certain advantages. It is well known, simple, and fairly well understood—having been used for some time in the construction industry (calculated back to the year 1903). This index was established in 1921 to diagnose and track the wild fluctuations in prices after World War I. The quantity factors are:

(1) 200 hours of common labor (including fringe benefits),
(2) 25 CWT of structural steel,
(3) 1.088 Mbf of 2 by 4's S4S lumber,
(4) 6 barrels of cement.

This gives a rudimentary idea of the cost of building materials used in general heavy construction as well as the cost of common labor. In addition, the ENR Construction Index is published monthly over a fairly broad base, using data from 20 selected cities. The disadvantages possessed by this index with respect to sewage treatment plant construction are:

(1) It does not include the most important commodities used (process equipment and skilled labor) in this type of construction—a quantity bias.
(2) It does not represent materials cost-in-place or even on the job, which could differ substantially from the wholesale prices of these same materials—a price bias.
(3) It uses a weighting that is not representative of modern design and construction practices—a weight bias.

The development of a satisfactory index requires the elimination of all or as many as possible of the disadvantages inherent in existing indexes; namely, the quantity, weight, and price biases. A new index must also be comparable throughout the required period in which comparisons are to be made. Continuity for former periods can only be maintained by calculating backward in time and there are many reasons why this is sometimes not possible. The labor rates involved constitute an important reason, especially where the series is long or where there have been several changes in the components of the index. In addition, the original data used in computations years ago may not be readily available, requiring time and resources to assemble. Sometimes such data are not available.

There are two possibilities which might be investigated for the elimination or reduction of the biases inherent in available indexes. The first would necessitate the use of part of the various general construction index data (*5, 6, 7, 8*) and/or primary data from other sources, e.g., Department of Commerce Reports, Bureau of Labor Statistics (BLS) Reports, and business and government magazines or journals, to construct, by estimating quantity and weight parameters, an index number for sewage treatment plant construction. This alternative would require that the quantities and weights be estimated and there

is considerable uncertainty as to the accuracy with which this could be done.

The second alternative, the one developed herein, is the construction of an econometric model from real prices and quantities for a statistically representative sewage treatment plant utilizing published price data that are available for the period investigated. Theoretically, this is the best method to pursue, for the index does reflect the true quantities it represents. Furthermore, this index has the obvious advantage of being its own test for the base period. Having a fixed base, surveys could be made from time to time to see if the base still reflects sewage treatment plant construction practice. This method will provide a good measuring stick to study the trends and magnitude of sewage treatment plant construction in constant dollar values.

ASSUMPTIONS AND BASE DATA FOR INDEX

In the development of this construction cost index for sewage treatment plants, designed as a fixed base, weighted index, certain assumptions were made:

1. The hourly output of labor remains constant in spite of changing wage rates. That is, when the wage rates rise (or fall) because labor supply lags behind (or exceeds) demand, the hourly output of labor is assumed to remain constant.
2. The quantities and kinds of materials used will remain constant and available during the periods under study.
3. Modern treatment plant construction techniques date back to the year 1930.

Within the limitations of these assumptions, the index may be used for (*a*) estimating construction and equipment costs at various dates; (*b*) checking present costs with costs for similar work during previous years; (*c*) verifying other cost data; and (*d*) forecasting future cost trends.

Weighting

This index does not reflect the cost of land; engineering, legal, and fiscal services; and errors, omissions, and changes subsequent to con-

tract award. It does include the following "indicators" that are common to sewage treatment works: (*a*) cost of materials, (*b*) cost of process equipment, (*c*) construction labor cost, (*d*) contractor's plant costs (contractor's equipment), and (*e*) overhead and profit. Process equipment is peculiar to sewage treatment works.

Base Period

In order to provide a comparable base to other Federal indexes, the 36-month period January 1, 1957, through December 31, 1959, was selected as a base for this index. This time period conforms to the postwar base period for Federal Index numbers as defined by the Bureau of the Budget.

Geographical Locations

Prices of materials and services vary considerably throughout the country. An index based on average prices and costs (countrywide) would not necessarily be acceptable for local or regional use. Consequently, regional indexes are necessary for each of the country's major commercial marketing areas for which price data are available. These areas, separated on a county line basis, represent areas of influence for each of the following 20 trade centers:

Atlanta, Ga.
Baltimore, Md.
Birmingham, Ala.
Boston, Mass.
Chicago, Ill.
Cincinnati, Ohio
Cleveland, Ohio
Dallas, Tex.
Denver, Colo.
Detroit, Mich.
Kansas City, Mo.
Los Angeles, Calif.
Minneapolis, Minn.
New Orleans, La.
New York, N.Y.
Philadelphia, Pa.
Pittsburgh, Pa.
St. Louis, Mo.
San Francisco, Calif.
Seattle, Wash.

These trade centers are those for which *Engineering News-Record* publishes monthly price data. The National Index is based on the sum of the cost of identical plants built in each of the 20 city areas. A map showing the 20 cities and their assigned areas of influence is to be found in appendix A (*9*).

Design Characteristics of Model Plant

An analysis of contract awards for sewage treatment plants, assisted under the Federal Water Pollution Control Act during the period 1956 through 1962, revealed an average hydraulic capacity of 1.34

million gallons daily (MGD), a design population of 12,000, and a contract cost of $40 per capita (*10, 11*). The most frequent treatment process was the high rate trickling filter. This information was to provide the basis for the design of a hypothetical plant, but since there is very little difference in the physical size of the structural components or hydraulic requirements of a 1.34-MGD and a 1.0-MGD high rate trickling filter plant, a 1.0-MGD plant was used as the model for the cost index. Since various types of sewage treatment plants are now being constructed, allowances were made to incorporate unique units in the model plant in order that the index would be valid for all types of municipal waste treatment works. The cost estimate of this plant was predicated on idealized conditions, representing minimal costs under circumstances prevailing in Kansas City, Mo., in August 1962. Design data and a layout of the plant are included in appendix B. Design characteristics are as follows:

General. The plant was designed for a population of 10,000 people, an average flow of 1.0 MGD, a maximum flow of 2.5 MGD, a biological oxygen demand (BOD) of 200 mg/l, a recirculation ratio of 1½ to 1, and an overall BOD reduction of 92 percent.

The plant includes a comminutor, with a bar screen serving as a bypass device, Parshall flume, preaeration tank with grit removal, primary sedimentation tanks, a settled sewage pumping station with provision for recirculation, high rate trickling filters, secondary sedimentation tank, chlorine contact tank, primary and secondary digesters, and a sludge filter building which also contains an office and laboratory. Sludge drying beds are provided as an auxiliary feature. Facilities to allow for prechlorination and postchlorination are also provided.

Flow Through the Plant. The plant flow is divided into the following segments:

(1) By gravity through the comminutor, Parshall flume, preaeration tanks, and primary sedimentation tanks;

(2) By pumping from the wet well following the primary sedimentation tanks to a distribution box for gravity application to the trickling filters; and

(3) By gravity from the trickling filters to the secondary sedimentation tank, recirculation structure, chlorine contact tank, and to the outfall sewer.

Recirculation of Flow. Recirculation of plant flow is accomplished by a pneumatically operated valve and piping system connecting the recirculation structure with the wet well of the pumping station. The operation of this valve is automatically controlled by the sewage level in the pumping station wet well using an air bubbler system.

Sludge collected in the primary sedimentation tanks is pumped to the digester and sludge from the secondary sedimentation tank is recirculated, by pumping, to the aerated grit chambers.

Bypass Connections. Provision for bypassing is provided as follows:

(1) Between the comminutor and the Parshall flume,
(2) From the wet well of the pumping station,
(3) Between the trickling filters and the secondary sedimentation tank, and
(4) From the recirculation structure.

Maintenance. Separate drains are provided in each of the basins to allow for cleaning and maintenance. The piping and layout of the aerated grit chambers and primary sedimentation tanks are arranged so that any combination of these chambers and tanks can be removed from service.

Other. Provision is made for doubling the capacity of the plant. All utilities are available at the plant site.

DEVELOPMENT OF COST INDEX

Category Assignment

To develop the cost index it was necessary to consider the various major categories of a construction job, in this instance the hypothetical treatment plant. The construction categories were assigned as follows:

A. Excavation and fill,
B. Reinforced concrete,
C. Miscellaneous iron and steel,
D. Pipe, valves, and fittings,
E. Process equipment, pumps, and motors,
F. Sand and rock for filter media and drying bed fill,
G. Buildings, and
H. Other items.

As discussed earlier, the costs of land; engineering; legal and fiscal services; errors, omissions, and changes subsequent to contract award are not included since the index is predicated on a contract cost basis. For the purpose of estimating these excluded items, an allowance of 20 percent of contract cost can be used.

Basis for Unit Construction Cost. To obtain the unit construction costs for the model plant, it was necessary to determine quantities of material and labor required to build the plant. This was done by a quantity analysis of materials and labor for the model plant, utilizing prices and wages prevailing in the Kansas City area during August 1962, as locally reported.

Unit Prices for Material and Labor. To provide for a continuing pricing basis, the estimated material prices and labor wages ascertained by the study of data from the Kansas City area were compared with the corresponding prices and wages reported by *Engineering News-Record* to be prevailing in Kansas City, Mo., during August 1962. Where differences were found, the ENR unit value prevailed and the quantity of the unit was adjusted to produce the predetermined dollar value for the component. This caused a slight modification in design quantities. The modified design quantities were used with the reported unit prices for each of the 20 cities included in this report. Appendix C lists the various materials and labor that comprise these components for each category of construction of the model plant.

Process Equipment. Process equipment required a unique approach, as an analysis of the literature, manufacturers' catalogs and brochures, and discussions with consulting engineers disclosed no standardized units of weights or measures as well as no continuing published pricing data. Since it was found that the process equipment (category E) amounts to approximately $156,000, or 34 percent of the total plant construction cost, it became necessary to establish a common frame of reference which could be priced on a continuing basis from regularly reported unit prices.

Consultation with equipment manufacturers disclosed that process equipment factory prices closely follow the production cost of the following combination of materials with an equal allowance for labor.

	Percent
Steel and machine products	90
Castings and forgings	10

The process equipment factory prices, however, are f.o.b. point of manufacture and do not include freight, royalties, resale, and the other after plant costs. The BLS (*12*) wholesale prices, which include these after plant costs, were selected for use with this category as follows:

Structural Steel Shapes—for steel and machine products,
and
Pig Iron, No. 2, Foundry—for casting and forgings.

An index curve was developed using these materials in the previously defined ratio for the process equipment based on the BLS wholesale prices. This curve was submitted to the manufacturers for comparison and comment. In practically every instance, the index curve was in close agreement with the manufacturers' experience. This is demonstrated graphically in appendix D.

Construction Component Costs

The following fundamental components are normally used in cost analyses of construction work: (*a*) material, (*b*) labor, (*c*) contractor's plant costs, and (*d*) overhead and profit. Since material, labor, and contractor's plant cost data were available for the model plant, these components were used as a starting point in developing the cost index. The fourth component, overhead and profit, was estimated on a percent basis of the three preceding determinate values. The allowance for overhead and profit was obtained by using approximately 15 percent of material costs, 15 percent of contractor's plant costs, and 25 percent of the labor cost.

The table on page 11 shows the component costs for the eight construction categories used in the development of the index.

The following assumptions and explanations refer to the categories in the table.

1. It was assumed that the materials used for forms and shoring for reinforced concrete could be used three times.
2. Category (F), Sand and Rock, includes only the filter media of the trickling filters and the sand fill of the sludge drying beds.
3. Category (G), Buildings, includes the cost of concrete block, brick, doors, and windows, etc., but does not include framing costs which are included under iron and steel or reinforced concrete.
4. Category (H), Other Items, includes the costs of plumbing, heating and ventilating, electrical and other items.

Category Division

A review of several studies (*13*, *14*, *15*, *16*, *17*, *18*, *19*) made on the construction cost of sewage treatment plants revealed that materials are, indeed, the chief cost ranging from 48 to 74 percent for all types of plants, and between 54 and 66 percent for trickling filter plants. Labor ranged from a low of 20 percent to a high of 29 percent, and the "other" (contractor's plant, overhead and profit, etc.) ranged from a low of 16 percent to a high of 19 percent. The distribution of construction cost for the hypothetical plant shown in the table is in close agreement with these findings.

Construction Categories, Components, Costs and Percent of Costs for a 1.0 High Rate Trickling Filter Plant (Kansas City, Mo.—August 1962)

Construction category	Material cost		Labor cost		Contractor's plant		Overhead and profit		Total category cost	
	Dollar value	Percent of category	Dollar value	Percent of category	Dollar value	Percent of category	Dollar value	Percent of category	Dollar value	Percent of plant
A. Excavation and Fill	$7,370.99	17.01	$11,184.44	25.82	$18,144.91	41.88	$6,615.28	15.28	$43,315.62	9.376
B. Reinforced Concrete	49,295.33	43.91	41,837.98	37.27	3,874.41	3.45	17,287.97	15.40	112,259.59	24.297
C. Miscellaneous Iron and Steel	6,542.64	51.13	3,993.05	31.20	249.52	1.95	2,010.93	15.71	12,796.14	2.770
D. Pipes, Valves, and Fittings	26,241.57	56.51	13,244.17	28.52	1,030.31	2.22	5,922.53	12.75	46,438.58	10.051
E. Process Equipment, Pumps and Motors	118,659.63	75.92	14,409.93	9.22	3,766.59	2.41	19,453.79	12.44	156,289.94	33.826
F. Sand and Rock	9,259.18	52.62	4,631.26	26.32	1,002.99	5.70	2,702.96	15.36	17,596.39	3.808
G. Buildings	6,167.23	43.40	6,533.50	45.98	150.61	1.06	1,359.30	9.57	14,208.74	3.075
H. Other Items	28,241.31	47.76	21,221.74	35.89	1,580.75	2.67	8,085.49	13.67	59,129.29	12.797
T. Total Plant	251,777.88	54.49	117,055.97	25.33	29,800.09	6.45	63,440.25	13.73	462,034.29	100.000

Computation of Total Category Cost

Since material and labor unit prices are the only cost values historically available in published form, it became necessary to express contractor's plant, overhead, and profit as a fixed percent of the labor and material cost. These percent values were determined from the estimated costs for these items as reported for the model plant (table, p. 11). This was done for each construction category in five steps as follows:

For Category A—August 1962:

(1) Material plus labor cost = $18,555.43
= 42.83 percent of total category cost

(2) Contractor's plant cost = $18,144.91
= 41.88 percent of total category cost

(3) Material plus labor plus contractor's plant cost = $36,700.34
= 84.71 percent of total category cost

(4) Overhead and profit cost = $6,615.28
= 15.28 percent of total category cost

(5) Total category cost for excavation and fill = $43,315.62
= 100 percent of total category cost

Extending Unit Prices To Obtain Total Material and Labor Cost. Unit prices were multiplied by the total quantity factors to determine the total quantity cost for each item. These total quantity costs were then combined to yield total category costs for construction in terms of material and labor. This is illustrated for each category in appendix C for the Kansas City, Mo., area.

The combined labor and material cost for each category was then increased by the appropriate percent values, allowing for contractor's plant, and overhead and profit, to obtain the total category cost. This procedure was followed for each of the 20 cities over the entire period of this study, using unit prices prevailing in each location. The sum of these total category costs for a given time determines the total plant construction cost for that period.

COMPUTATION OF NATIONAL INDEX

The first step in computing the national index was to determine the average plant cost for each of the 20 cities over the base period from January 1957 through December 1959. The sum of these 20 average values is the base for the index and equals 100.

The national index for any period is the ratio of the sum of the 20 cities' plant costs for that period, to the sum of 20 cities' average plant costs for the base period, multiplied by 100.

For example, the national index for August 1962 was calculated as follows:

Sum of the 20 cities' plant costs for August 1962 = $9,552,556.78
Sum of the 20 cities' average plant costs for base period = $8,928,457.60

$$\text{National index} = \frac{\$9,552,556.78}{\$8,928,457.60} \times 100 = 106.99$$

COMPUTATION OF INDIVIDUAL CITY INDEX

The plant index was determined for each city by substituting individual city total plant cost in the index formula. The base period plant cost is the sum of the average plant costs for the base period divided by 20. The ratio of the particular city's plant cost to the base period cost yields the city index. For August 1962:

Base period average plant cost = $446,422.88
Kansas City plant cost = $462,034.29

$$\text{Kansas City index} = \frac{\$462,034.29}{\$446,422.88} \times 100 = 103.49$$

The various category costs and plant costs for the 20 cities for the base period are included as appendix E. A graphic presentation of these costs (and indexes) for the Kansas City, Mo., area are included in appendix F.

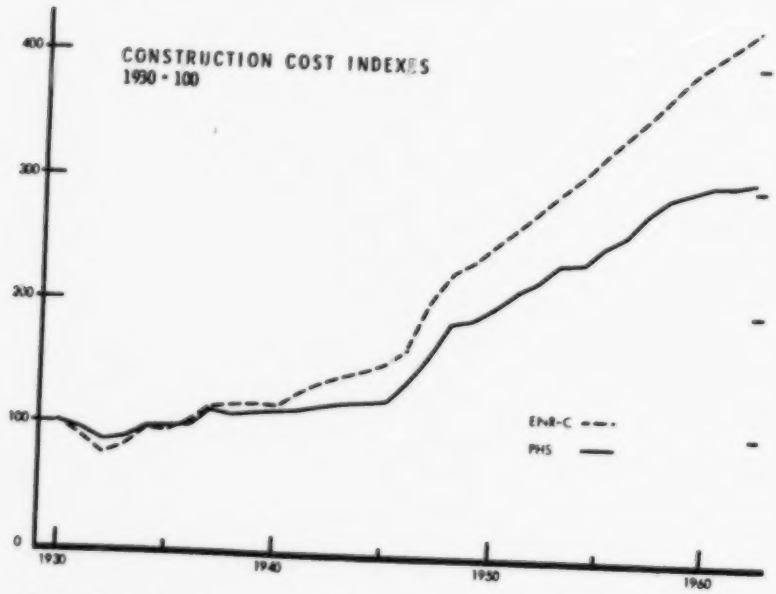
Price data for each of the 20 cities for the month of August for the years 1930 through 1962 were extracted from the ENR index and the BLS wholesale prices. Where these sources did not cover the entire range of time, interpolation was used based upon similarity of trades or materials at the commencement of the series. This was done primarily for labor values in the early 1930's. Electronic data processing equipment was used to calculate the individual city indexes and the national index for each year.

Plant indexes for each of the 20 cities, and the national index from 1930 through 1962 for the month of August, are tabulated in appendix G. These indexes will be extended on a monthly basis from current price data published by *Engineering News-Record* and the BLS wholesale prices.

DISCUSSIONS

Since waste treatment works have generally been considered to follow the ENR Construction Cost Index, a comparison of this index to the Public Health Service Sewage Treatment Plant (PHS–STP) Construction Cost Index was undertaken.

In order to compare the indexes, both were converted to a base of 1930=100. The converted PHS–STP Index is included in appendix G and is shown graphically in the following figure, along with the converted ENR–C Index.



Only during 1930–40 did the two indexes follow a similar path. Since 1940 there has been a widening divergence between the PHS–STP Index and the ENR–C Index. Based on 1930=100, these indexes in 1962 were 430 for ENR–C and 310 for the PHS–STP Index.

A comparison of the last 6 years disclosed that the ENR–C Index has increased at a rate almost twice as great as the PHS–STP Index. This period of time coincides with the period of increased activity in the municipal waste treatment works construction field.

Because the PHS–STP Index is based on information peculiar to sewage treatment plant construction, its value for this specialized field is believed to be much greater.

In order to insure that the PHS–STP Index continues to reflect current practice in the sewage treatment plant construction industry, revaluation of the index base will be undertaken periodically at intervals of not over 10 years. Alteration, revision, or modification of the index may be required by changes in amount and/or kinds of materials, new developments, or uses of process equipment. Changes in construction methods and techniques will also be considered in each revaluation.

CONCLUSIONS

(1) Comparison of the PHS–STP Construction Cost Index with the narrow-based, but widely accepted, ENR Construction Cost Index disclosed that there were substantial differences.

(2) The PHS–STP Index is believed to be representative of cost changes peculiar to municipal sewage treatment plant construction.

(3) The study shows that although sewage treatment plant construction costs have increased steadily during the last 30 years, the rate of increase has declined since 1956.

(4) This index may be used to evaluate past construction activity and to estimate future sewage treatment plant construction cost requirements for the 20 areas of influence in the United States as well as for the Nation as a whole.

(5) As an indicator of sewage treatment plant cost trends and as a service to the public, the PHS–STP Index will be extended on a monthly basis, and reexamined periodically to account for changes in fundamental assumptions.

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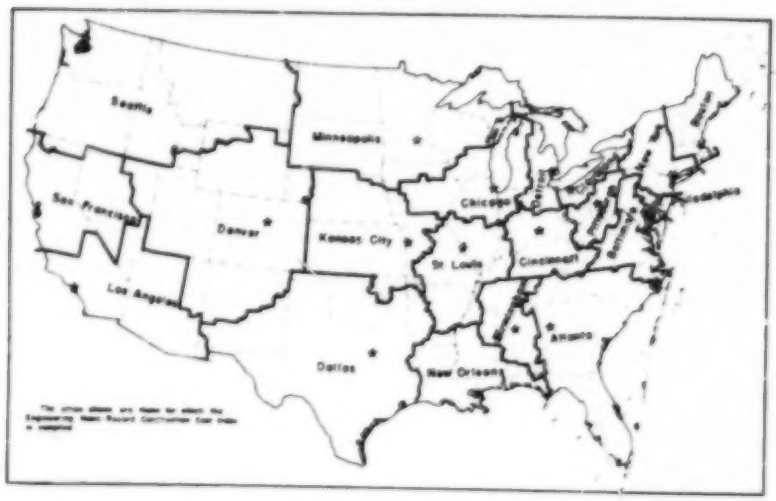
Appendices

APPENDIX A

The 20 Index Cities and Their Assigned Areas of Influence



APPENDIX B

Design Data for a 1.0-MGD High Rate Trickling Filter Plant

DESIGN SPECIFICATIONS

1. *Comminutor and Parshall Flume*

The comminutor structure and comminutor are sized for an average flow of 1.0 MGD and a maximum flow of 2.5 MGD. The channel of the comminutor structure is 1'3" wide. With the use of stop plates, flow can be diverted either through the comminutor or a hand-cleaned bar screen.

The Parshall flume has a 12" throat and is sized on the same basis as the comminutor. This is the only metering device used in the treatment plant.

2. *Preaeration Chamber*

The preaeration chamber includes two rectangular units with a combined detention time of 45 minutes based on a flow of 1.0 MGD. The inside dimensions of each chamber are 8'0" wide, 26'0" long, and a water depth of 11'0".

Aeration is provided by blowers forcing air through diffusers. Each blower is sized to deliver 70 cfm of free air. This amount of air allows for 0.1 cubic foot per gallon of sewage based on a flow of 1.0 MGD. These blowers are sized so that one unit shall act as a standby.

Mechanical grit-collecting equipment provides for removal of collected grit and a manually operated skimmer is used to remove scum.

3. *Primary Sedimentation Tank*

This tank contains two parallel operated mechanically cleaned rectangular units, at design flow having combined rates of: Surface settling rate, 1,000 gpd per square foot; detention time, 1.5 hours; weir rates, 10,000 gpd per linear foot.

The inside dimensions of each tank are 12'6" wide, 40'0" long, with an average water depth of 8'4".

A manually operated skimmer is used to remove scum.

4. *Pumping Station*

The pumping station has three 1.0-MGD, constant speed, vertical-turbine-type pumps which are located directly above the wet well. Space is provided for the installation of two additional pumps when required for plant expansion.

These pumps are automatically controlled by the levels of the sewage in the wet well using an air bubbler system, to maintain a flow of 3 MGD to the trickling filters, providing a recirculation ratio of from 1.5 to 1 to 0.2 to 1 as total plant flow varies. The pumps discharge through a 12" discharge line to the distribution box.

The wet well dimensions are 7'0" wide, 26'0" long, and the depth below the pump base is 14'0".

5. *Trickling Filter*

The trickling filters consist of two units. The hydraulic loading on each filter of 10 MGD based on a total plant flow of 1.5 MGD. Each unit has an inside diameter of 65'0" and the minimum filter media depth above the underdrains is 6'0".

For future needs, provision is made in the distribution box to service two additional filters.

The rotary distributor and jets for each filter are sized for a minimum rate of 520 gpm and a maximum rate of 870 gpm.

6. *Secondary Sedimentation Tank*

Secondary settling is provided by a single, mechanically cleaned, rectangular tank having a surface settling rate of 800 gpd per square foot. Weir rates, 10,000 gpd per linear foot. Design flow for this unit is 1.5 MGD.

This tank is 25'0" wide, 75'0" long, and has an average water depth of 8'0".

7. *Chlorine Contact Tank*

The rectangular chlorine contact tank has a detention time of 45 minutes based on a flow of 1.0 MGD. The tank dimensions are 16'0" wide, 26'0" long, and the average water depth of 10'0". Wood baffles are placed to prevent currents and to allow for adequate mixing of the chlorine.

8. *Chlorinators*

Two automatically controlled, solution-fed chlorinators are provided. One chlorinator feeds the influent end of the aerated grit chamber and the other chlorinator feeds the chlorine contact tank. These chlorinators are located together in a well-ventilated building with automatic chlorine detection devices for safety purposes.

The chlorine storage building is equipped with a hoist and a hoist rail for unloading chlorine cylinders from a truck. This building has space available to store seven 1-ton cylinders.

9. *Digesters*

Two digesters are provided--one for primary, and one for secondary sludge. A structure, located between the digesters, houses the heat exchanger, motor control center, and sludge pumps.

The primary unit is 25′0″ inside diameter and has a capacity of 1.0 cubic feet per capita based on 10,000 population. This unit has a fixed cover and the sludge is heated and mixed with two draft-tube-type mixers.

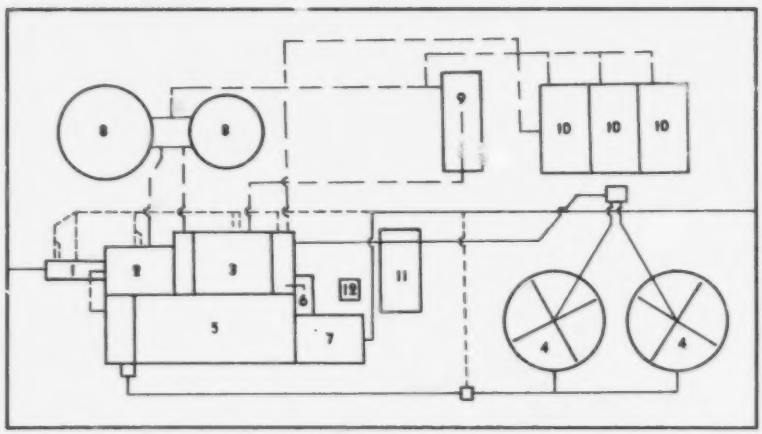
The secondary unit is 35′0″ inside diameter and has a capacity of 2.0 cubic feet per capita based on 10,000 population. This unit has a floating cover and the sludge is not mixed or heated.

10. *Sludge Filter Building*

This building contains a vacuum filter, chemical storage space, laboratory and office. The filter is designed for an allowable loading of 6 pounds dry solids per square foot per hour. Provision is made for conditioning chemicals.

11. *Sludge Drying Beds (Auxiliary)*

The drying beds consist of three underdrained rectangular units. Dimensions of each unit are 40′0″ wide, 60′0″ long, with earthen sides. These beds allow for a loading of 0.75 square foot per capita based on 10,000 population.



Plan View of the Public Health Service Index 1.0-MGD High Rate Trickling Filter Plant

1. Comminutor and Parshall flume
2. Preaeration Grit Chamber
3. Primary Settling Tank
4. High Rate Trickling Filter
5. Final Settling Tank
6. Recirculation Structure
7. Chlorine Contact Tank
8. Sludge Digesters
9. Sludge Filter Building
10. Sludge Drying Beds
11. Chlorine Storage Racks
12. Chlorination Building

APPENDIX C

Material and Labor Cost Analysis of the Construction Plant at Kansas City,

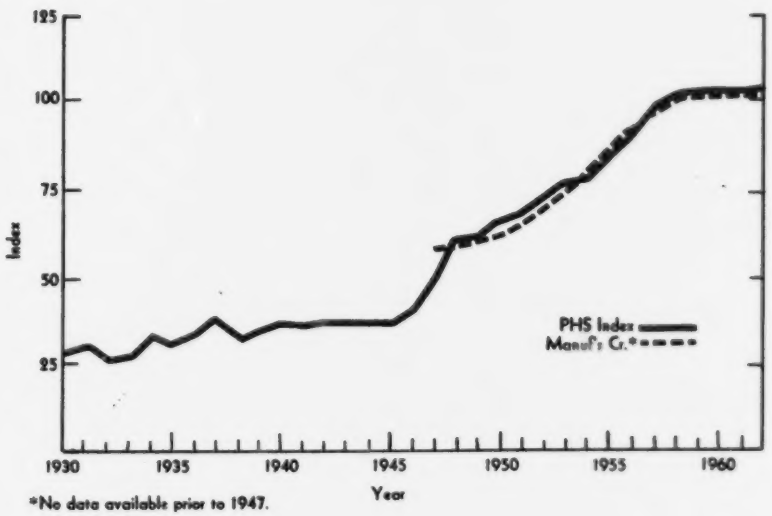
Category	Material			
	Components	Quantity	Unit cost	Item cost
Excavation and Fill	Rock (cu yd)	1, 559. 05	$2. 10	$3, 274. 00
	Earth and sand (cu yd)	2, 156. 31	1. 90	4, 096. 99
				7, 370. 99
Reinforced Concrete	Transit mixed concrete (cu yd)	1, 793. 42	13. 50	24, 211. 17
	Reinforcing steel (100 lbs)	2, 196. 15	7. 10	15, 592. 66
	Plyform (1,000 sq ft)	46. 30	205. 00	9, 491. 50
				49, 295. 33
Miscellaneous Iron and Steel	Structural shapes (100 lbs)	192. 21	10. 34	1, 987. 45
	Cast Iron (tons)	6. 88	138. 60	953. 57
	Reinforcing steel	507. 27	7. 10	3, 601. 62
				6, 542. 64
Piping, Valves, and Fittings	Cast Iron (tons)	127. 69	138. 60	17, 697. 83
	Vitrified clay pipe (ft)	747. 45	3. 751	2, 803. 68
	Reinforced concrete pipe (ft)	1, 952. 40	2. 94	5, 740. 06
				26, 241. 57
Process Equipment, Pumps and Motors	Structural steel shapes (100 lbs)	15, 392. 86	6. 167	94, 927. 77
	Pig iron, No. 2 Foundry tons)	356. 87	66. 50	23, 731. 86
				118, 659. 63
Sand and Rock	Crushed stone (tons)	3, 017. 14	2. 10	6, 335. 99
	Sand (tons)	267. 37	1. 90	508. 00
	Common brick (1,000)	61. 92	39. 00	2, 415. 19
				9, 259. 18
Buildings	Concrete block (each)	9, 883. 64	. 22	2, 174. 40
	Common brick (1,000)	28. 07	39. 00	1, 094. 73
	Structural steel (100 lbs)	280. 28	10. 34	2, 898. 10
				6, 167. 23
Other Items	Structural steel shapes (100 lbs)	3, 663. 50	6. 167	22, 592. 80
	Pig iron, No. 2 Foundry (tons)	84. 94	66. 50	5, 648. 51
				28, 241. 31
Total Plant				

Categories for a 1.0-MGD High Rate Trickling Filter Mo., Aug. 1, 1962

Labor				
Class/Trade	Man-hours	Unit cost	Item cost	Category cost
Equipment operators	2, 040. 67	$3. 845	$7, 846. 38	
Common labor	1, 159. 05	2. 88	3, 338. 06	
			11, 184. 44	$18, 555. 43
Carpenters	2, 727. 80	3. 875	10, 570. 22	
Equipment operators	1, 054. 57	3. 845	4, 054. 82	
Ironworkers	1, 406. 57	4. 025	5, 661. 44	
Common labor	7, 483. 16	2. 88	21, 551. 50	
			41, 837. 98	91, 133. 31
Ironworkers	662. 61	4. 025	2, 667. 01	
Common labor	460. 43	2. 88	1, 326. 04	
			3, 993. 05	10, 535. 69
Ironworkers	2, 193. 20	4. 025	8, 827. 63	
Common labor	1, 535. 52	2. 88	4, 416. 54	
			13, 244. 17	39, 485. 74
Iron workers	1, 563. 30	4. 025	6, 292. 28	
Common labor	2, 818. 63	2. 88	8, 117. 65	
			14, 409. 93	133, 069. 56
Bricklayers	314. 46	4. 325	1, 360. 04	
Common labor	1, 135. 84	2. 88	3, 271. 22	
			4, 631. 26	13, 890. 44
Bricklayers	697. 11	4. 325	3, 015. 00	
Carpenters	361. 03	3. 875	1, 398. 99	
Common labor	735. 94	2. 88	2, 119. 51	
			6, 533. 50	12, 700. 73
Electrical workers	3, 108. 00	4. 50	13, 986. 00	
Common labor	2, 512. 41	2. 88	7, 235. 74	
			21, 221. 74	49, 463. 05
				368, 833. 85

APPENDIX D

Sewage Treatment Plant Process Equipment—Manufacturers' Composite Experience Curve and Public Health Service Process Equipment Index Curve [1957–59= 100]



*No data available prior to 1947.

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APPENDIX E

Total Plant and Category
[Base period

Cities	A Excavation and Fill	B Reinforced Concrete	C Miscellaneous Iron and Steel
Atlanta	$38, 968. 84	$102, 780. 01	$12, 279. 14
Baltimore	44, 987. 34	106, 917. 38	12, 864. 07
Birmingham	38, 346. 71	99, 453. 02	12, 088. 07
Boston	46, 405. 67	115, 605. 53	13, 222. 69
Chicago	47, 959. 21	112, 281. 77	12, 381. 49
Cincinnati	44, 215. 51	110, 280. 43	13, 083. 64
Cleveland	48, 986. 24	118, 404. 79	12, 309. 09
Dallas	38, 404. 74	96, 963. 79	12, 430. 90
Denver	33, 549. 13	101, 193. 47	12, 902. 00
Detroit	48, 214. 81	115, 094. 40	12, 605. 16
Kansas City	38, 064. 57	107, 001. 00	12, 359. 98
Los Angeles	44, 360. 65	107, 830. 16	12, 426. 52
Minneapolis	43, 582. 71	113, 942. 45	13, 145. 45
New Orleans	35, 781. 02	98, 666. 13	11, 623. 00
New York City	45, 979. 51	131, 252. 81	14, 074. 87
Philadelphia	45, 450. 78	113, 417. 21	13, 001. 86
Pittsburgh	46, 440. 61	113, 255. 40	12, 128. 17
St. Louis	44, 389. 23	111, 130. 01	12, 704. 97
San Francisco	41, 929. 21	113, 169. 69	13, 947. 90
Seattle	48, 924. 66	111, 937. 89	13, 290. 28

Costs for 20 Index Cities
=1957–59]

D Pipes, Valves, and Fittings	E Process Equipment Pumps and Motors	F Sand and Rock	G Buildings	H Other Items	T Total Plant
$39, 666. 30	$147, 551. 33	$15, 305. 22	$11, 181. 23	$50, 734. 54	$418, 466. 64
41, 768. 17	150, 111. 63	19, 042. 68	12, 204. 83	52, 238. 85	440, 134. 97
37, 536. 12	148, 125. 56	17, 351. 12	11, 246. 13	50, 814. 61	414, 961. 39
45, 383. 76	151, 738. 62	16, 103. 60	13, 452. 13	54, 348. 44	456, 260. 39
46, 665. 89	153, 025. 61	18, 910. 08	13, 719. 77	56, 203. 55	461, 147. 33
41, 437. 68	150, 980. 72	19, 570. 56	13, 116. 51	54, 408. 80	447, 090. 94
44, 081. 30	153, 034. 36	24, 476. 48	13, 917. 71	56, 210. 82	471, 420. 75
38, 758. 30	147, 754. 25	15, 956. 77	12, 438. 25	50, 561. 91	413, 268. 83
40, 988. 08	149, 278. 50	14, 565. 64	12, 452. 99	52, 520. 43	417, 450. 19
46, 008. 11	152, 870. 31	19, 989. 20	14, 225. 80	56, 794. 93	465, 802. 75
41, 105. 66	150, 132. 54	15, 774. 13	12, 762. 89	53. 611. 04	430, 811. 81
45, 822. 95	152, 130. 06	18, 094. 30	12, 572. 86	56, 138. 26	449, 375. 78
48, 644. 77	15[illegible], 786. 75	23, 192. 07	12, 833. 13	54, 083. 41	460, 210. 75
39, 564. 92	147, 840. 29	14, 034. 11	12, 692. 99	50, 913. 94	411, 116. 39
48, 053. 44	155, 340. 89	18, 160. 31	15, 652. 91	59, 108. 81	487, 623. 61
46, 040. 45	152, 377. 02	18, 481. 90	14, 024. 06	56, 138. 83	458, 932. 06
45, 219. 28	151, 609. 05	17, 325. 70	14, 084. 44	56, 792. 89	456, 855. 53
42, 366. 08	151, 559. 16	16, 154. 48	14, 132. 55	56, 237. 34	448, 673. 78
45, 715. 20	152, 116. 13	18, 002. 70	14, 287. 67	56, 149. 54	455, 318. 11
46, 582. 22	151, 738. 44	21, 618. 97	14, 260. 67	55, 182. 43	463, 535. 61

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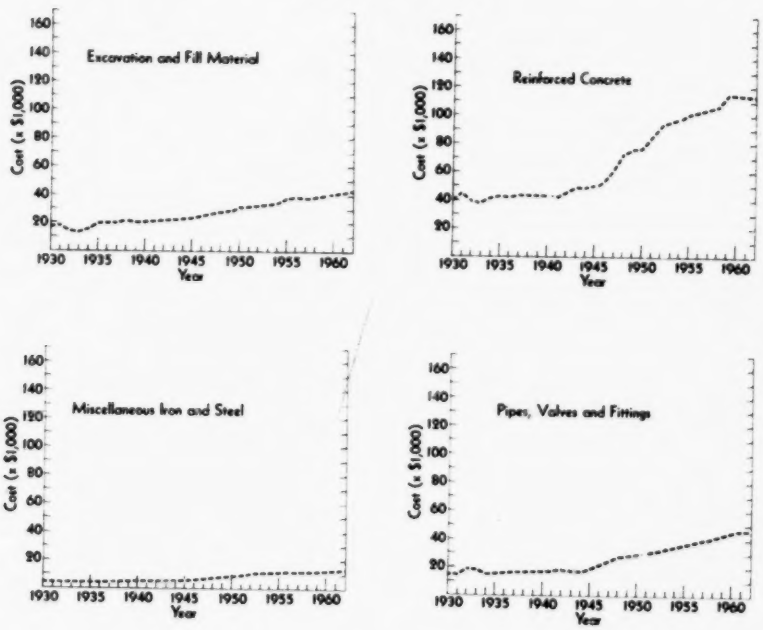
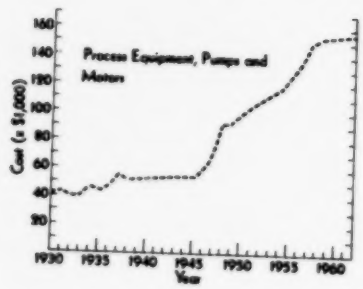
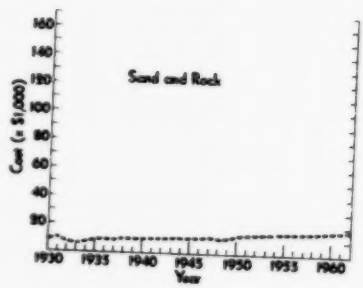
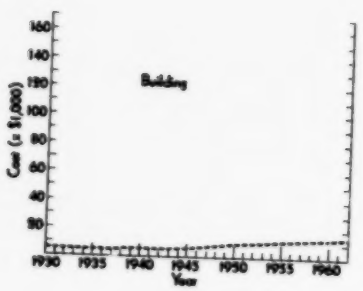
APPENDIX F

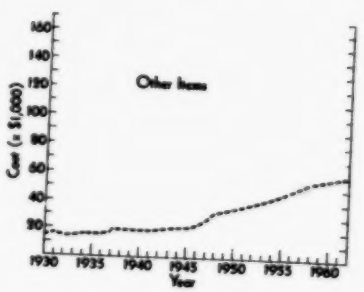
Cost Curves by Category for a 1.0-MGD High Rate Trickling Filter Plant, Kansas City, Mo., August 1930–62 [1957–59=100]

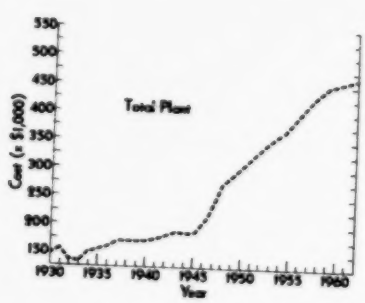



Process Equipment, Pumps and Motors
Cost (x $1,000)
Year


Sand and Rock
Cost (x $1,000)
Year


Building
Cost (x $1,000)
Year


Other Items
Cost (x $1,000)
Year


Total Plant
Cost (x $1,000)
Year

APPENDIX G

Municipal Waste Treatment Plant Cost

[1957–59

Years	Atlanta	Baltimore	Birmingham	Boston	Chicago	Cincinnati	Cleveland	Dallas	Denver	Detroit	Kansas City
1930	29.37	34.02	32.37	34.33	37.26	36.00	39.06	35.24	37.51	31.86	32.45
1931	32.00	33.69	28.32	31.45	34.78	32.25	36.87	35.09	34.69	30.81	34.78
1932	31.25	32.53	27.33	31.42	32.81	31.22	31.26	30.24	31.31	29.07	30.35
1933	30.12	33.08	28.57	30.74	35.03	31.82	32.21	32.18	31.47	27.04	29.51
1934	33.43	35.17	30.12	33.79	36.75	34.00	37.10	33.72	35.30	30.78	33.53
1935	32.89	35.28	30.72	34.72	36.78	36.68	37.10	32.19	35.32	31.89	34.70
1936	34.19	35.74	32.31	34.58	37.08	35.06	37.66	33.03	35.24	32.35	35.82
1937	37.97	39.12	35.51	38.37	39.60	39.24	41.26	35.33	40.23	37.88	38.62
1938	36.45	37.95	33.64	37.16	39.95	37.24	39.32	35.45	39.03	35.82	38.24
1939	36.71	38.08	33.80	37.65	40.81	38.19	39.66	35.80	39.06	35.84	35.27
1940	37.37	38.59	34.44	38.54	40.75	39.24	40.04	36.55	39.44	36.45	38.47
1941	38.09	39.72	35.27	40.15	41.04	39.49	42.20	37.30	39.69	38.17	38.66
1942	38.31	40.55	38.30	41.99	42.21	40.19	41.99	40.79	39.69	40.01	39.82
1943	38.93	41.09	38.32	41.86	42.32	40.58	42.90	40.75	41.80	39.52	41.31
1944	39.00	41.20	38.32	42.68	42.31	40.78	43.90	41.37	41.46	41.00	41.34
1945	39.54	41.93	39.02	42.46	43.56	41.48	44.52	42.04	41.75	41.78	41.78
1946	45.94	47.19	43.87	46.69	47.26	46.14	50.14	46.54	46.52	46.82	46.39
1947	53.51	54.45	51.16	55.02	57.48	55.86	58.53	53.95	55.51	56.32	52.66
1948	61.06	63.69	59.92	66.27	66.38	66.44	67.04	62.69	63.55	65.64	62.20
1949	60.72	65.45	60.37	67.80	67.39	65.36	70.52	63.87	63.49	65.90	62.33
1950	64.91	69.41	63.37	71.22	70.39	69.07	74.33	66.15	67.58	72.06	68.25
1951	68.78	73.67	67.82	76.02	75.79	73.99	78.08	71.28	71.92	77.14	72.24
1952	71.08	76.48	71.10	78.47	78.96	77.22	83.11	72.61	73.68	80.42	76.08
1953	75.65	80.77	75.07	81.43	83.32	80.96	87.47	75.11	77.43	85.99	79.16
1954	76.45	82.02	76.31	84.10	85.59	83.41	89.14	76.74	78.53	88.10	81.24
1955	81.06	84.51	80.31	89.09	89.54	86.86	94.19	79.56	82.33	92.13	85.93
1956	86.48	89.30	85.08	94.76	95.92	92.17	99.18	84.53	86.15	97.66	90.08
1957	92.73	96.52	90.68	100.41	102.10	98.74	105.30	91.11	91.32	102.34	94.54
1958	96.05	100.08	93.75	103.36	104.50	102.15	107.04	93.64	94.10	105.65	97.70
1959	96.53	102.46	95.82	105.84	107.39	102.59	107.13	95.74	98.13	108.99	100.43
1960	97.71	103.29	98.08	106.88	107.51	104.73	108.71	96.64	99.43	109.88	101.72
1961	98.68	103.57	97.25	107.86	108.94	107.04	109.71	96.39	99.43	110.73	102.77
1962	100.31	105.19	96.86	108.27	109.41	107.54	110.62	97.23	101.16	111.70	103.49

Indexes, 1930–62, August Values

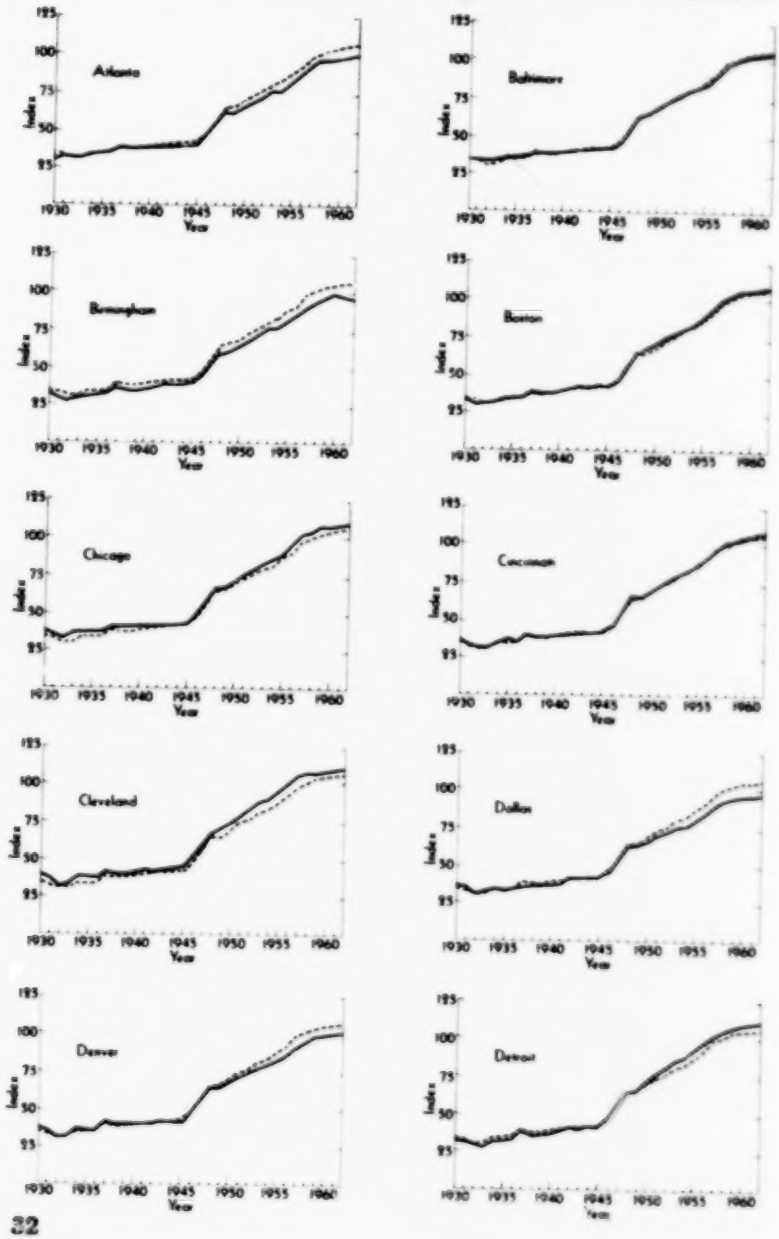
=100]

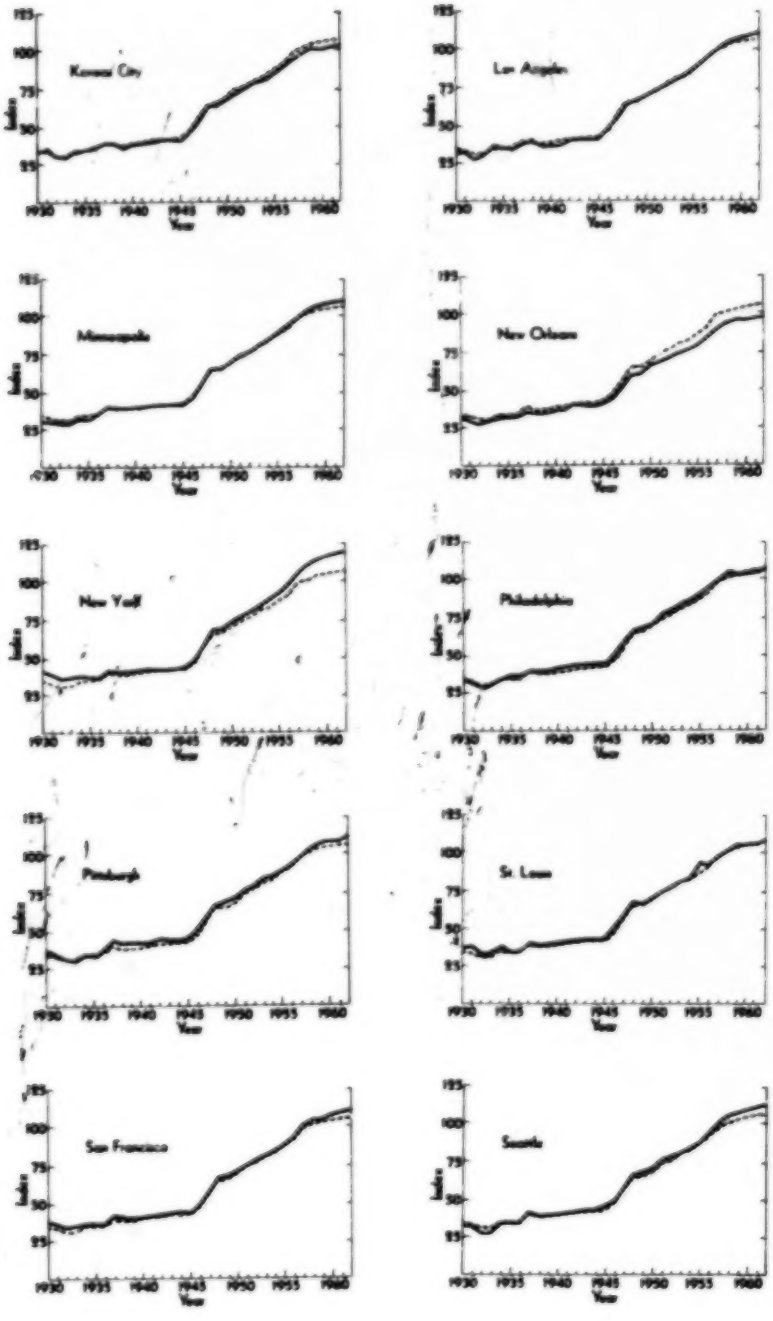
Los Angeles	Minneapolis	New Orleans	New York	Philadelphia	Pittsburgh	St. Louis	San Francisco	Seattle	National averages (1957–59=100)	National average (1930–100)	Year
30.88	30.97	31.16	41.30	33.93	35.18	36.56	37.17	31.92	34.43	100.00	1930
31.41	29.40	28.59	38.18	31.96	33.92	37.04	35.64	31.47	33.12	96.18	1931
27.08	28.14	27.31	35.71	28.46	30.23	32.56	33.97	27.37	30.48	88.51	1932
29.89	28.62	29.09	36.72	29.27	29.11	32.51	34.85	27.71	30.96	89.96	1933
35.59	31.58	31.66	37.29	34.29	32.99	36.78	35.26	33.33	34.12	99.08	1934
34.86	31.46	32.19	35.81	35.84	32.80	33.86	35.30	33.35	34.19	99.28	1935
33.68	34.94	32.26	36.24	36.25	35.98	34.81	35.96	33.52	34.84	101.17	1936
37.28	40.13	35.54	41.00	39.76	42.76	39.91	40.41	40.07	39.00	113.25	1937
38.36	38.40	34.49	39.68	38.17	40.81	38.12	38.79	38.40	37.77	109.68	1938
35.91	38.66	34.46	39.82	39.05	41.11	38.15	38.85	38.49	37.92	110.12	1939
35.91	39.12	36.90	40.33	40.73	40.47	39.65	39.70	36.67	38.57	112.00	1940
36.46	39.67	37.35	41.24	41.30	41.57	40.51	40.57	39.69	39.41	114.44	1941
40.00	40.34	40.51	41.59	43.15	43.79	41.86	41.98	41.20	40.92	118.83	1942
40.19	40.11	39.28	41.64	43.22	43.44	42.24	42.68	42.80	41.23	119.73	1943
40.19	40.70	39.27	41.89	44.33	42.67	42.38	42.97	42.69	41.57	120.72	1944
40.42	41.52	41.38	43.09	45.40	44.49	43.53	43.18	45.13	42.40	123.13	1945
48.50	45.68	44.19	47.61	49.00	49.48	49.24	47.96	48.20	47.17	136.96	1946
54.26	55.58	51.39	57.57	59.93	58.60	57.22	56.70	56.54	55.61	161.49	1947
64.87	65.13	59.87	68.16	65.53	66.75	66.90	66.16	66.69	64.75	188.03	1948
65.42	65.12	61.23	68.18	67.82	68.50	66.61	67.25	67.89	65.61	190.53	1949
68.54	69.19	65.98	73.27	71.04	71.67	69.05	70.18	70.79	69.32	201.30	1950
73.03	74.67	69.13	77.51	77.52	75.50	74.49	74.24	75.57	73.92	214.66	1951
76.31	76.19	71.47	80.41	79.80	78.39	77.39	77.49	78.52	76.76	222.91	1952
80.92	81.58	74.71	84.80	84.52	83.66	91.40	80.97	80.50	80.77	234.58	1953
82.79	84.56	76.00	88.20	86.47	85.09	83.15	83.88	84.33	82.80	240.45	1954
87.01	88.89	79.89	92.65	91.44	89.26	94.17	88.11	87.67	87.23	253.31	1955
92.45	94.27	85.17	99.05	95.13	91.49	92.02	92.41	94.12	91.87	266.79	1956
98.45	99.84	90.15	106.31	100.39	100.95	97.93	100.01	100.88	98.04	284.71	1957
102.61	104.50	93.43	110.44	105.76	104.06	102.07	103.47	105.57	101.80	294.75	1958
105.66	107.71	95.20	114.78	103.85	107.30	104.92	104.68	107.86	103.65	301.00	1959
107.86	108.80	96.09	116.19	104.52	108.20	105.54	108.08	109.29	104.96	304.80	1960
108.53	109.93	97.41	118.39	105.62	107.81	106.28	108.65	111.63	105.83	307.37	1961
110.66	110.10	98.98	119.48	107.82	110.84	108.29	109.51	112.49	106.99	310.70	1962

APPENDIX G—(Continued)

Individual City Indexes and National Index

City Index ——— **National Index** - - - -





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